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(54) **MODULAR LED LIGHTING SYSTEM**

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H05B 37/02 (2006.01)
H01J 13/32 (2006.01)

(52) **U.S. Cl.** **315/113**; 315/294; 362/217.13

(58) **Field of Classification Search** ..... 315/113, 315/209 R, 51, 246, 294, 297; 362/217.01, 362/217, 13, 217.14
See application file for complete search history.

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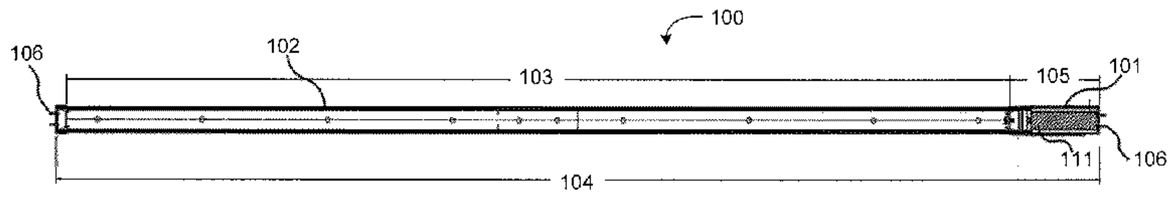
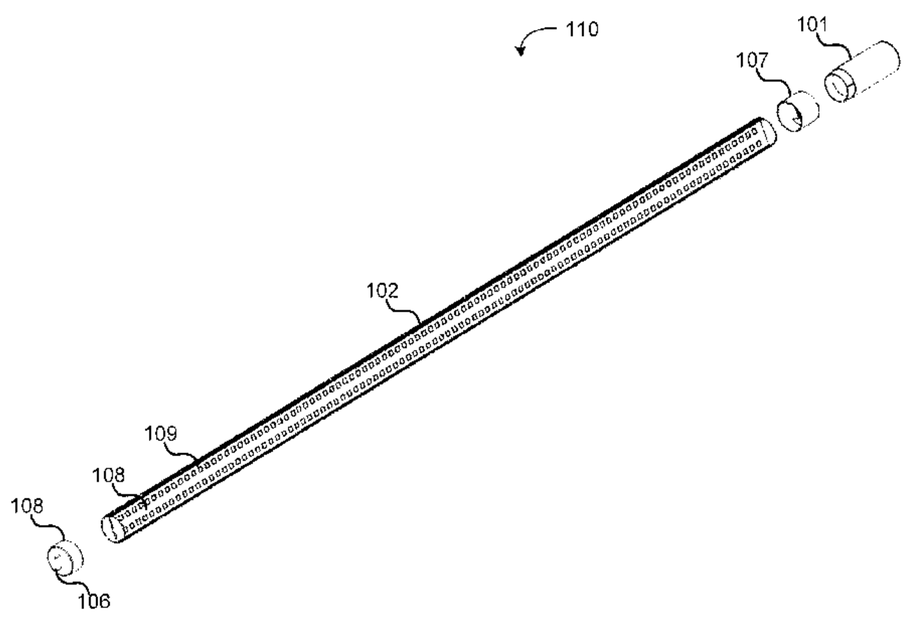
(57) **ABSTRACT**

According to various embodiments of the invention, an LED lighting system is providing having a replaceable driver module. In some embodiments, the replaceable driver module comprises a component that is physically attachable to an LED illumination module, whereby the attached components have a combined physical profile dimensioned for installation in a pre-existing light fixture. In further embodiments, the combined system's dimensions allow it to be installed in pre-existing fluorescent fixtures without requiring rewiring of the fixtures. In some embodiments, the LED driver module may be configured to condition power received from a fluorescent light ballast to drive the LEDs such that a pre-existing fluorescent ballast does not need to be removed. In other embodiments, the LED driver may be configured to condition main power such that a pre-existing fluorescent ballast may be removed.

18 Claims, 11 Drawing Sheets





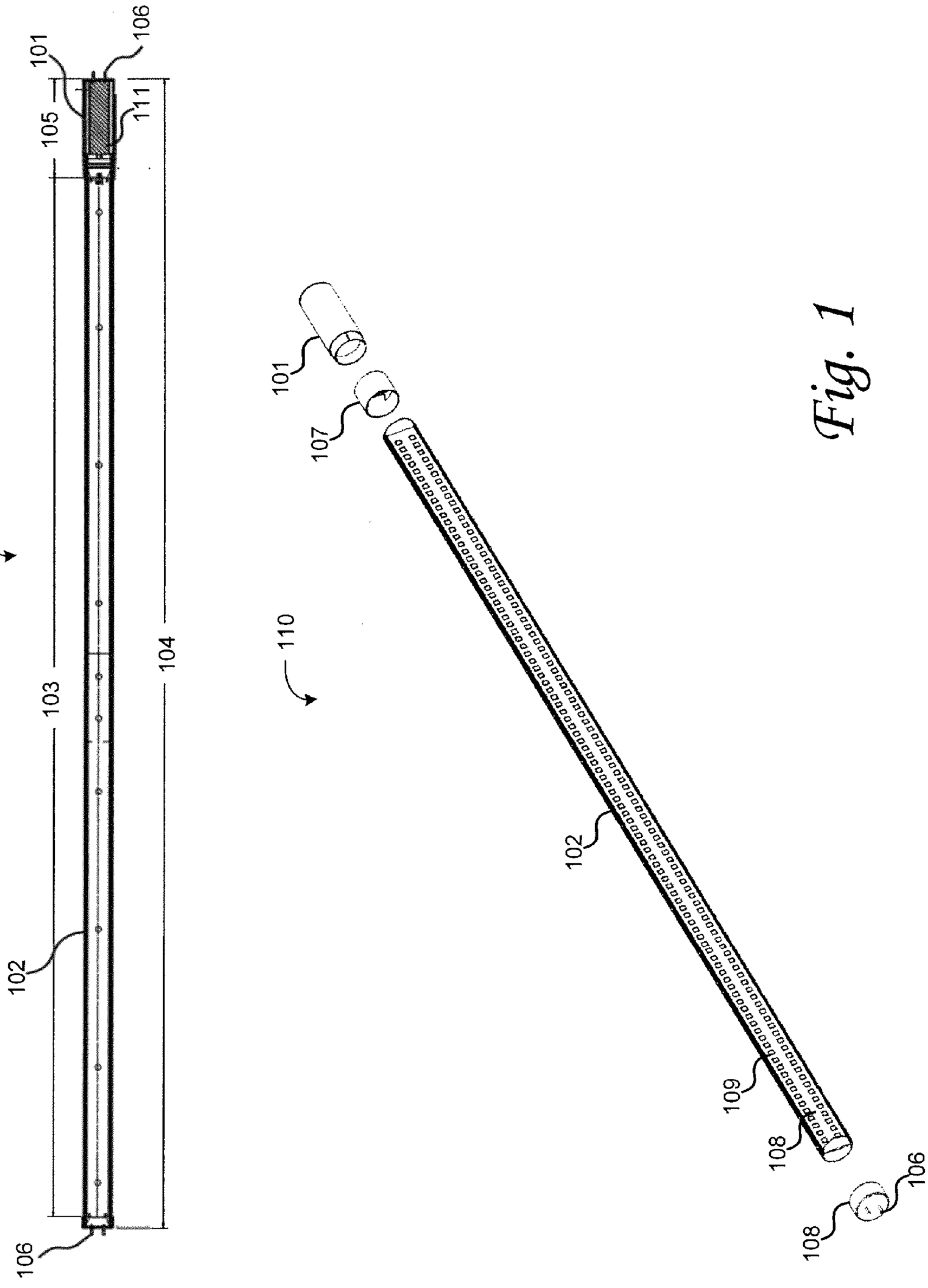


Fig. 1

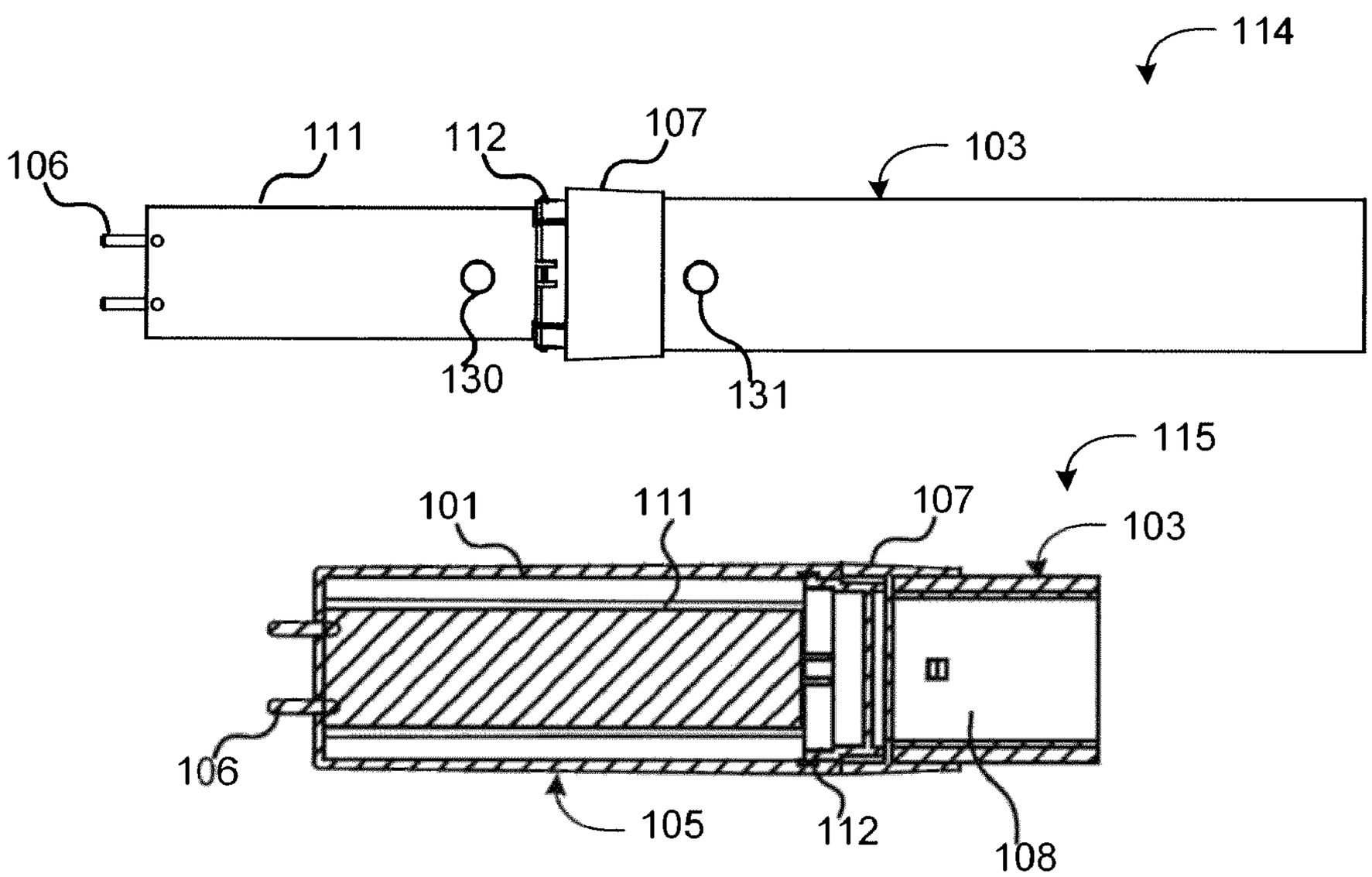

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Fig. 2

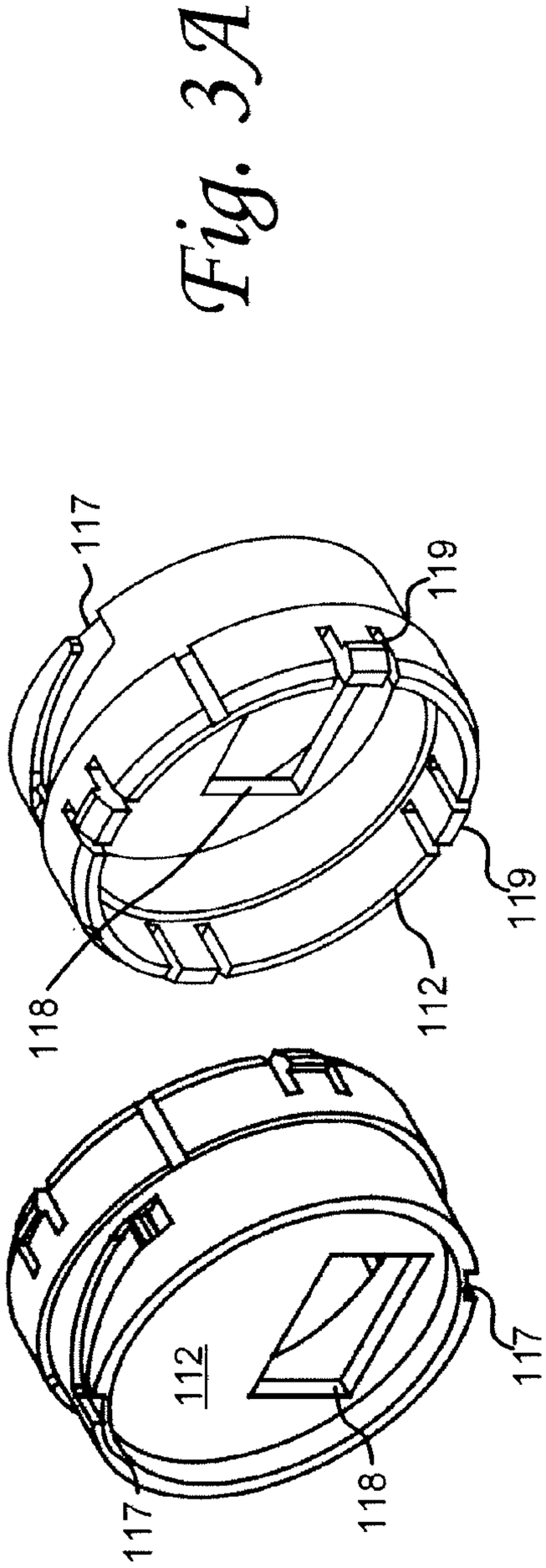


Fig. 3A

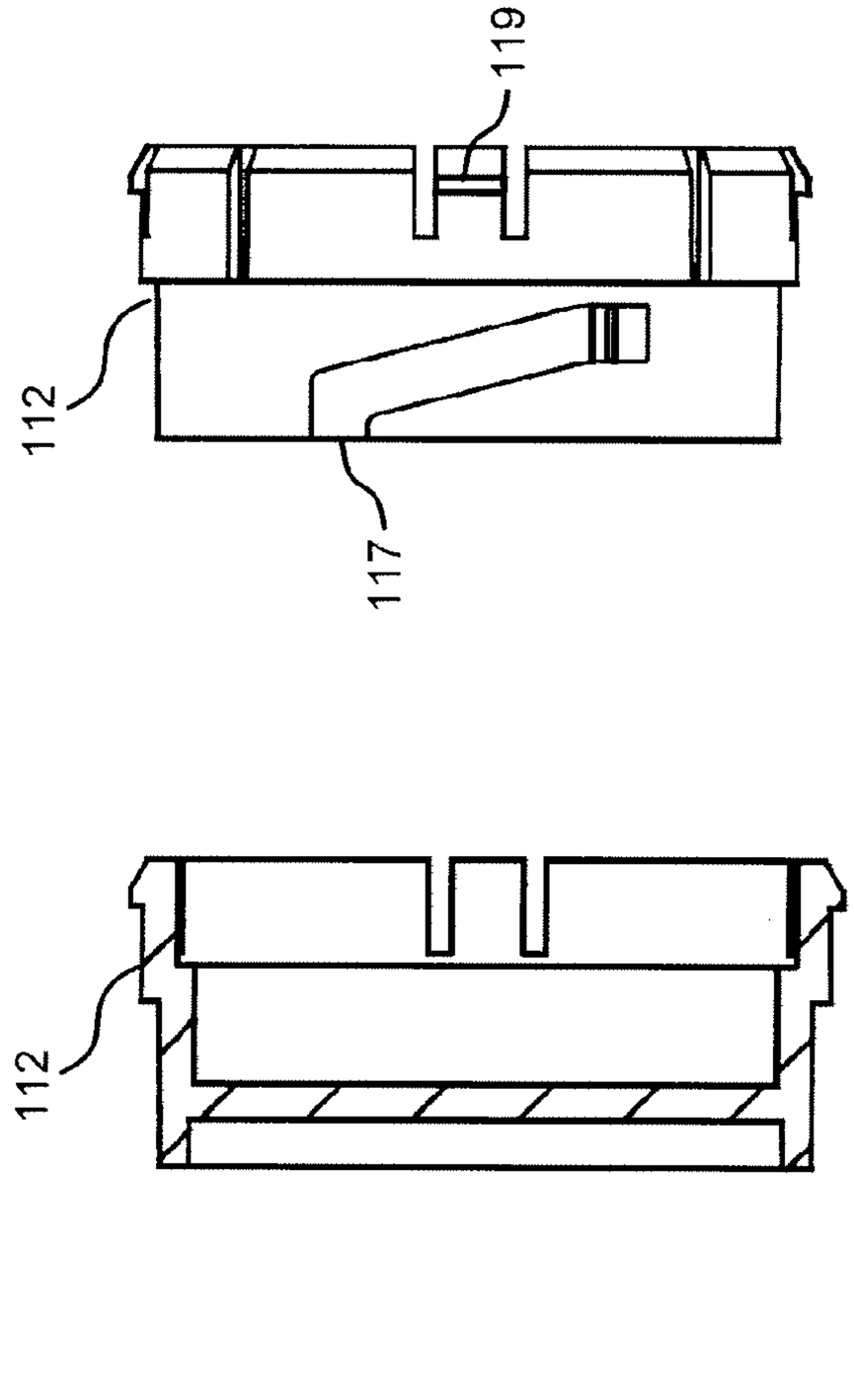


Fig. 3B

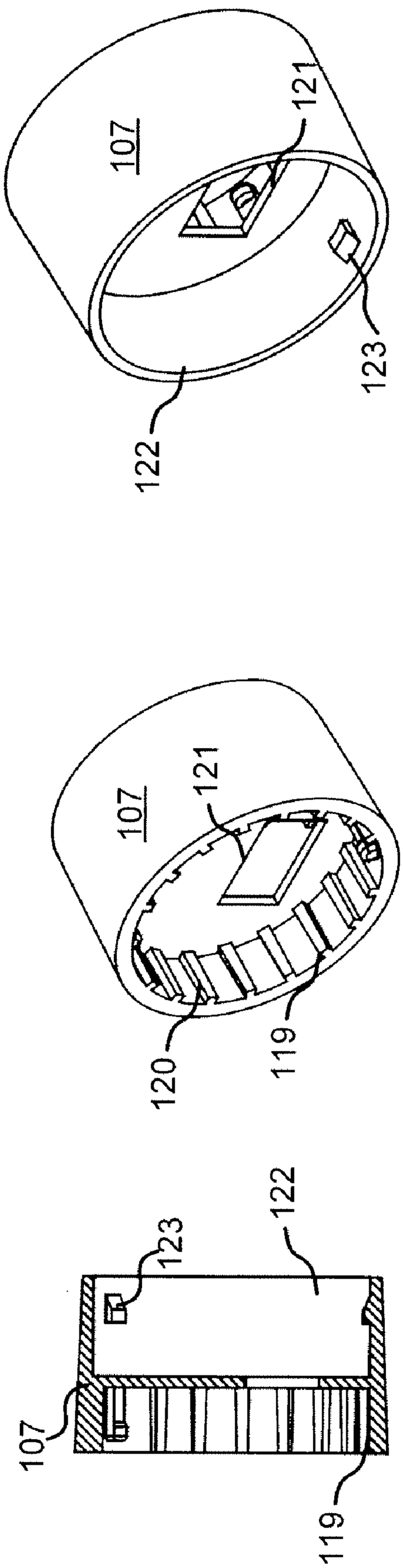


Fig. 4

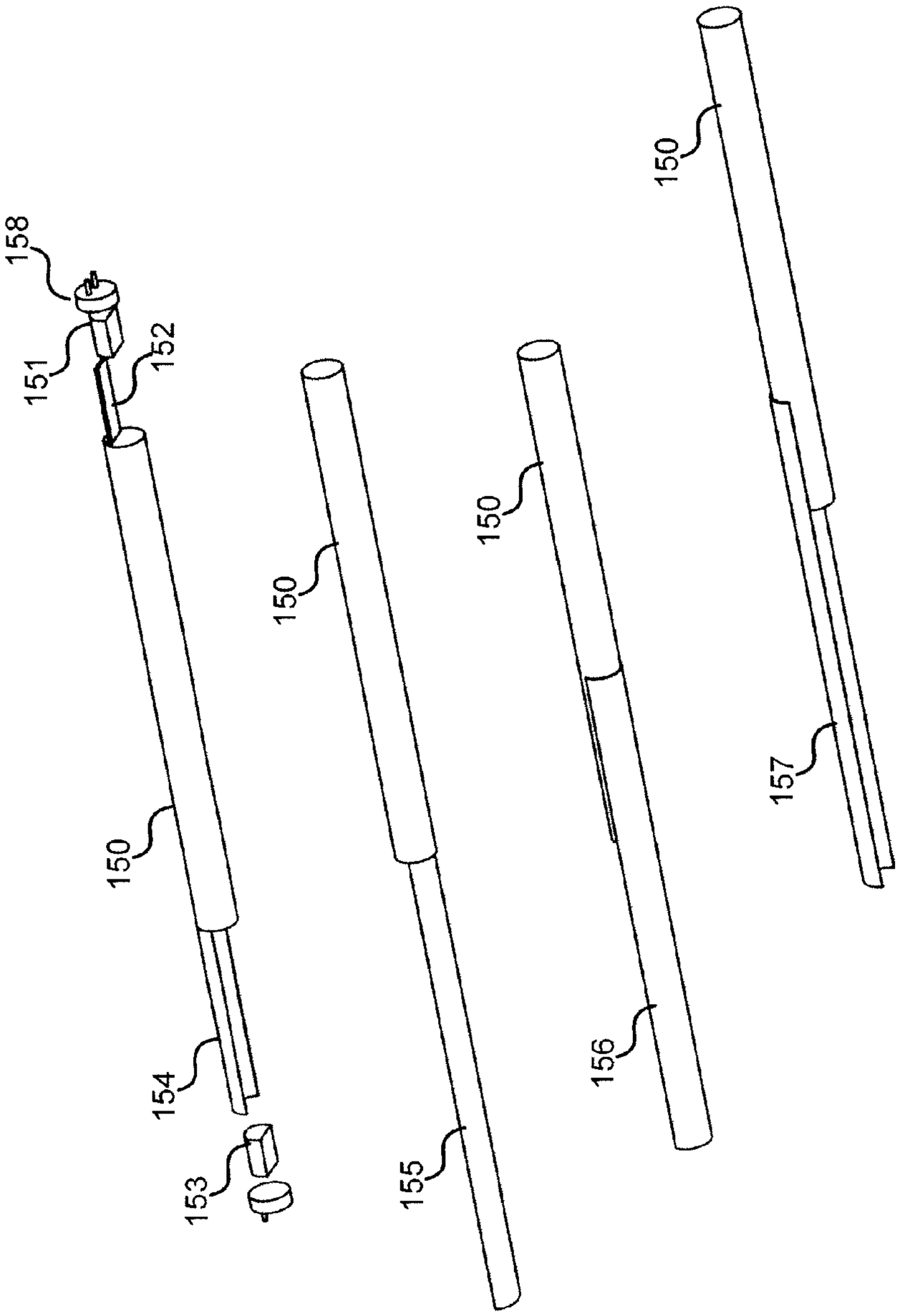


Fig. 5

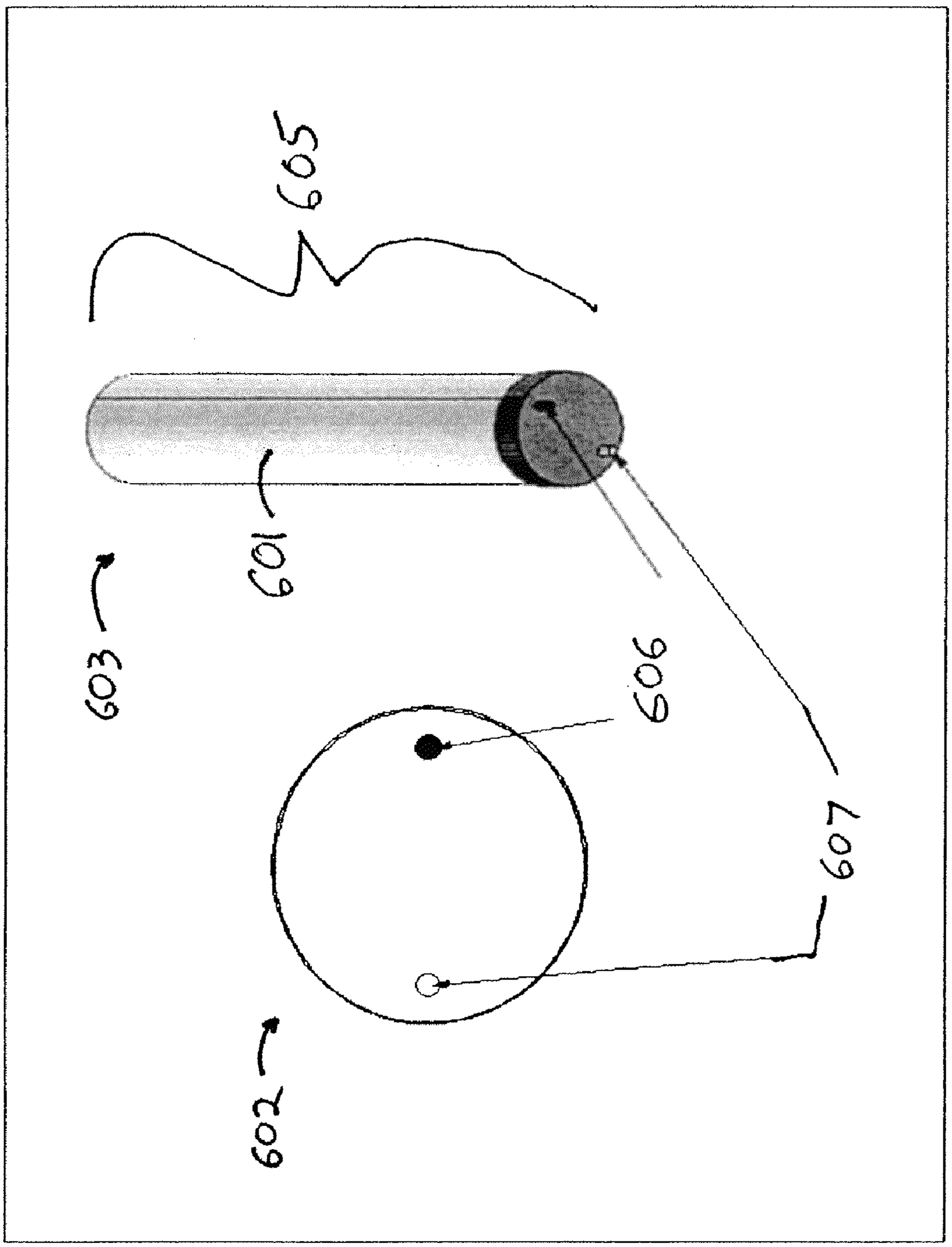


Fig. 6

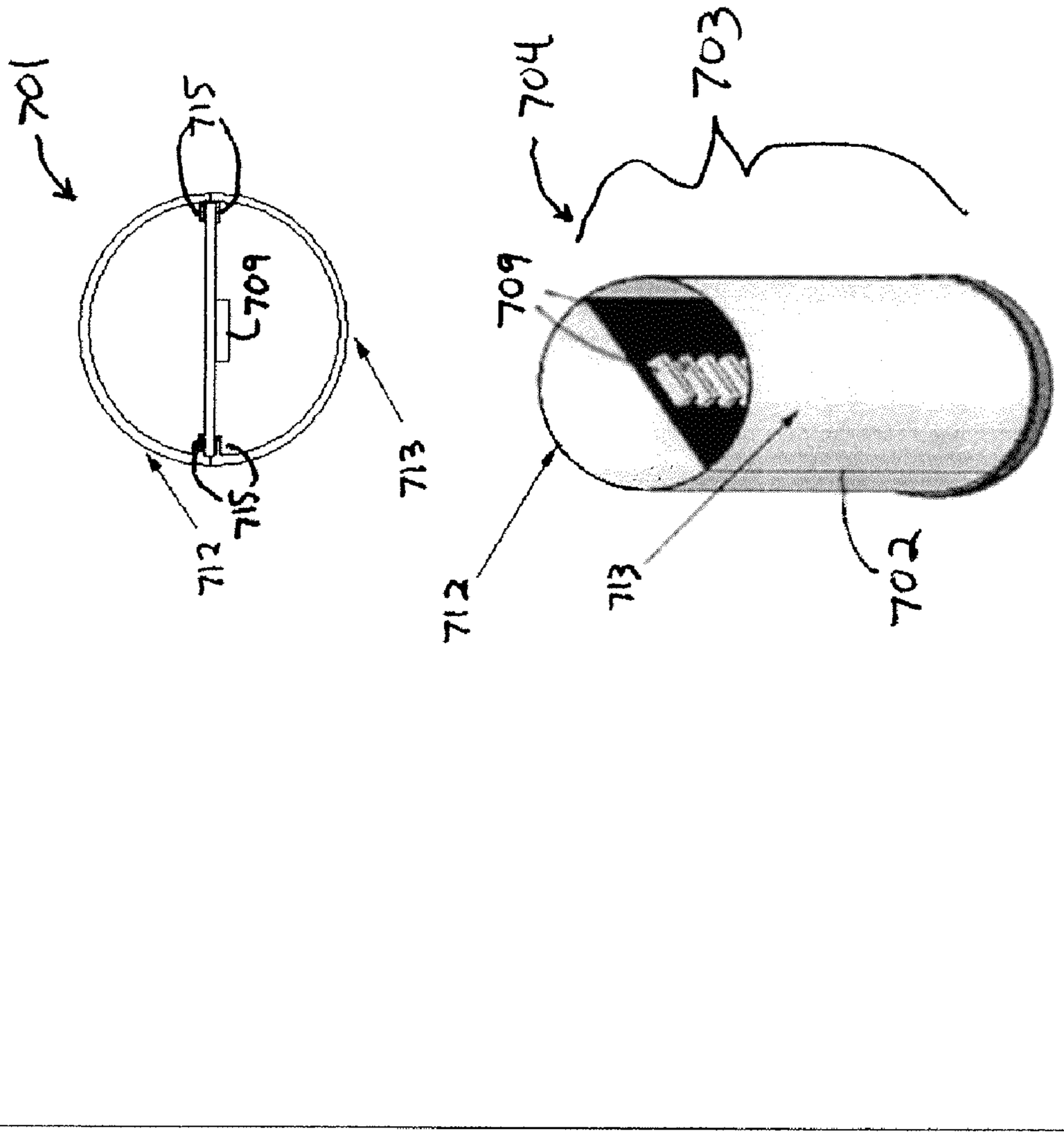


Fig. 7

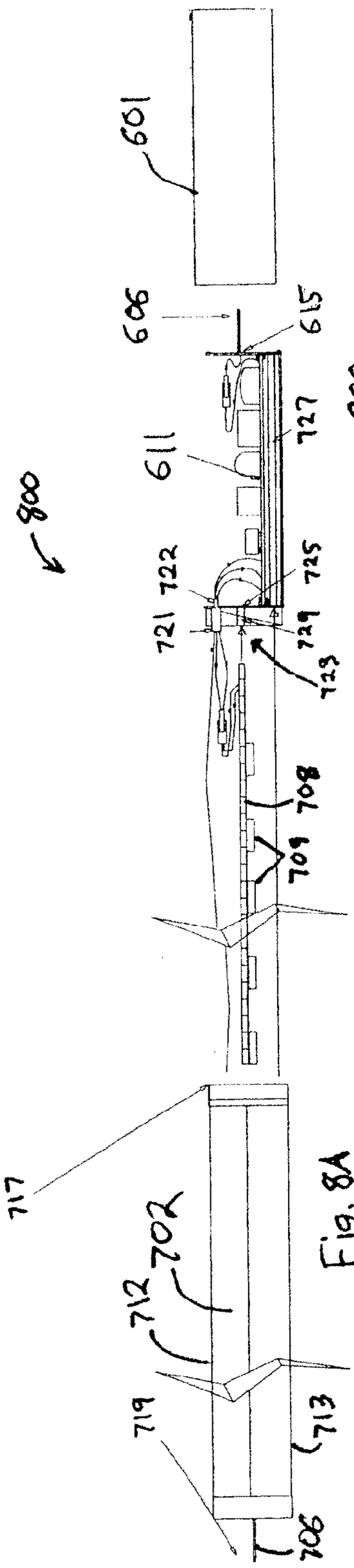


Fig. 8A

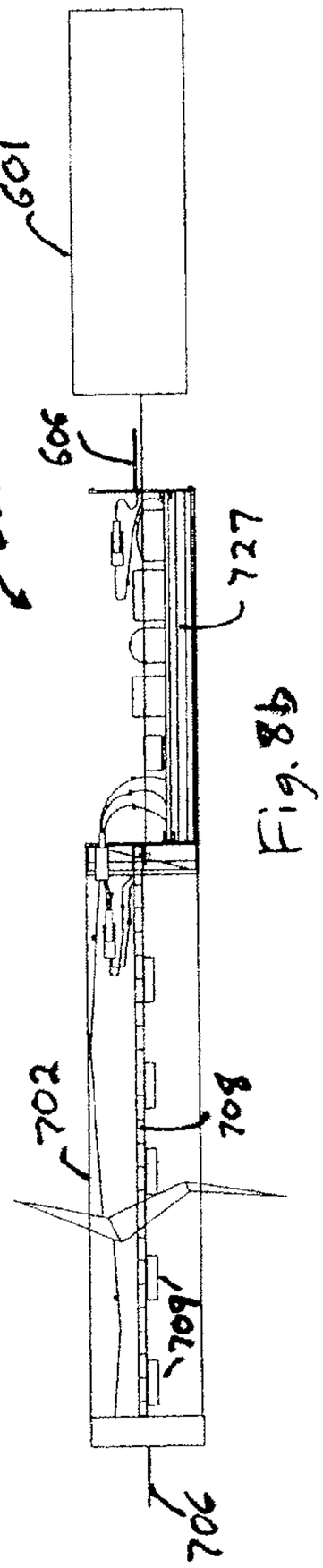


Fig. 8B

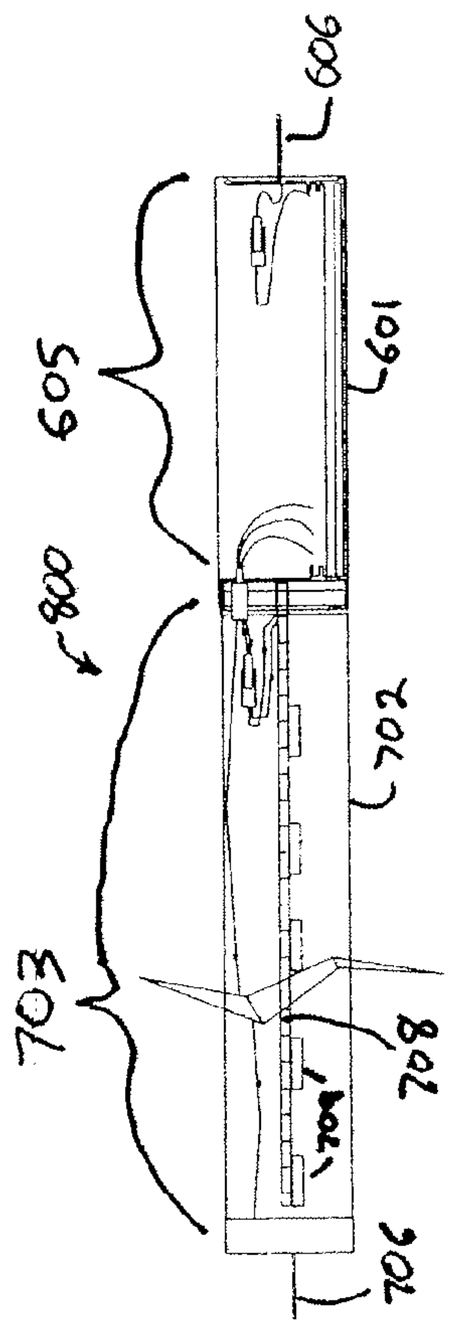


Fig. 8C

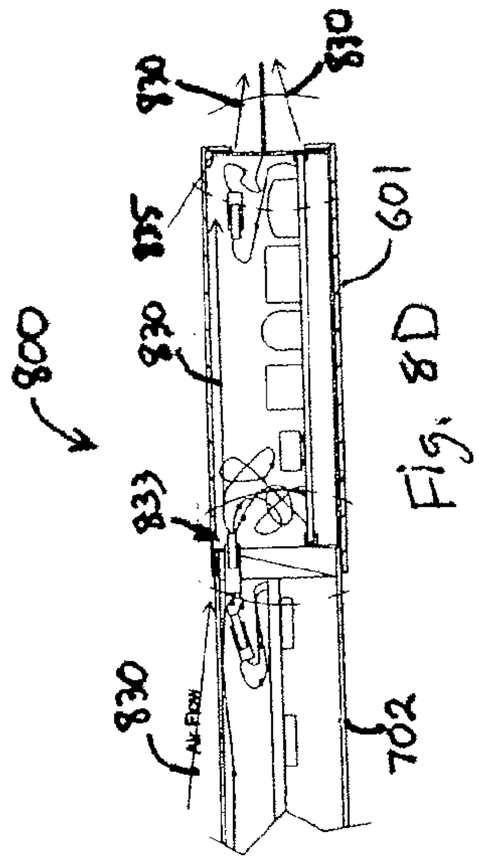
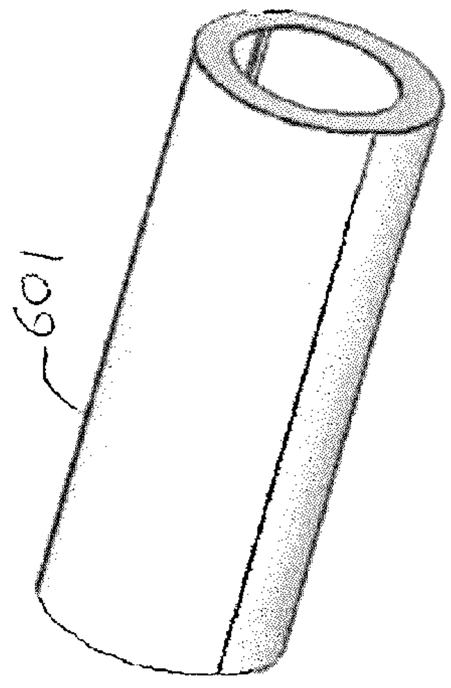


Fig. 8D



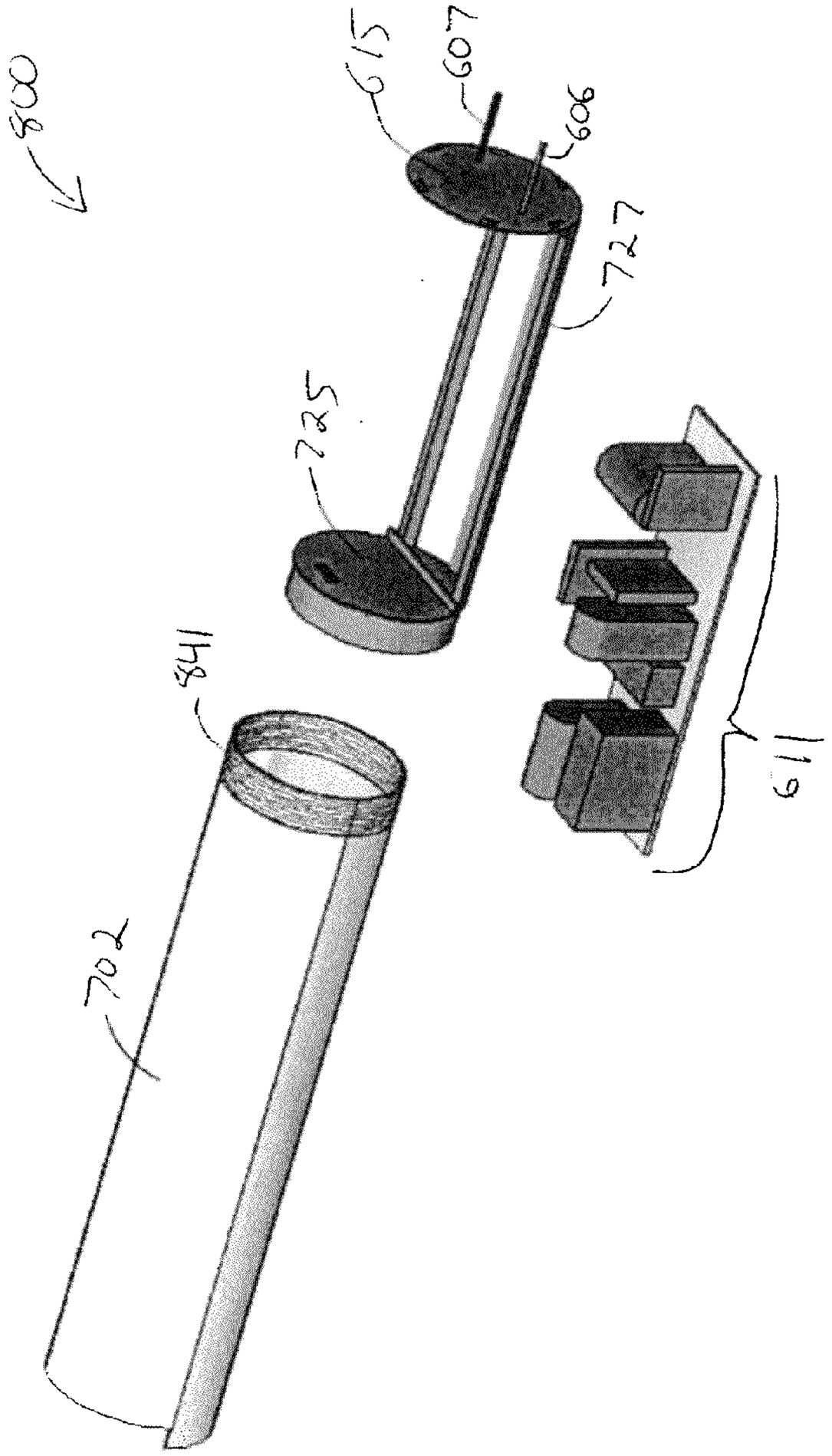


Fig. 9A

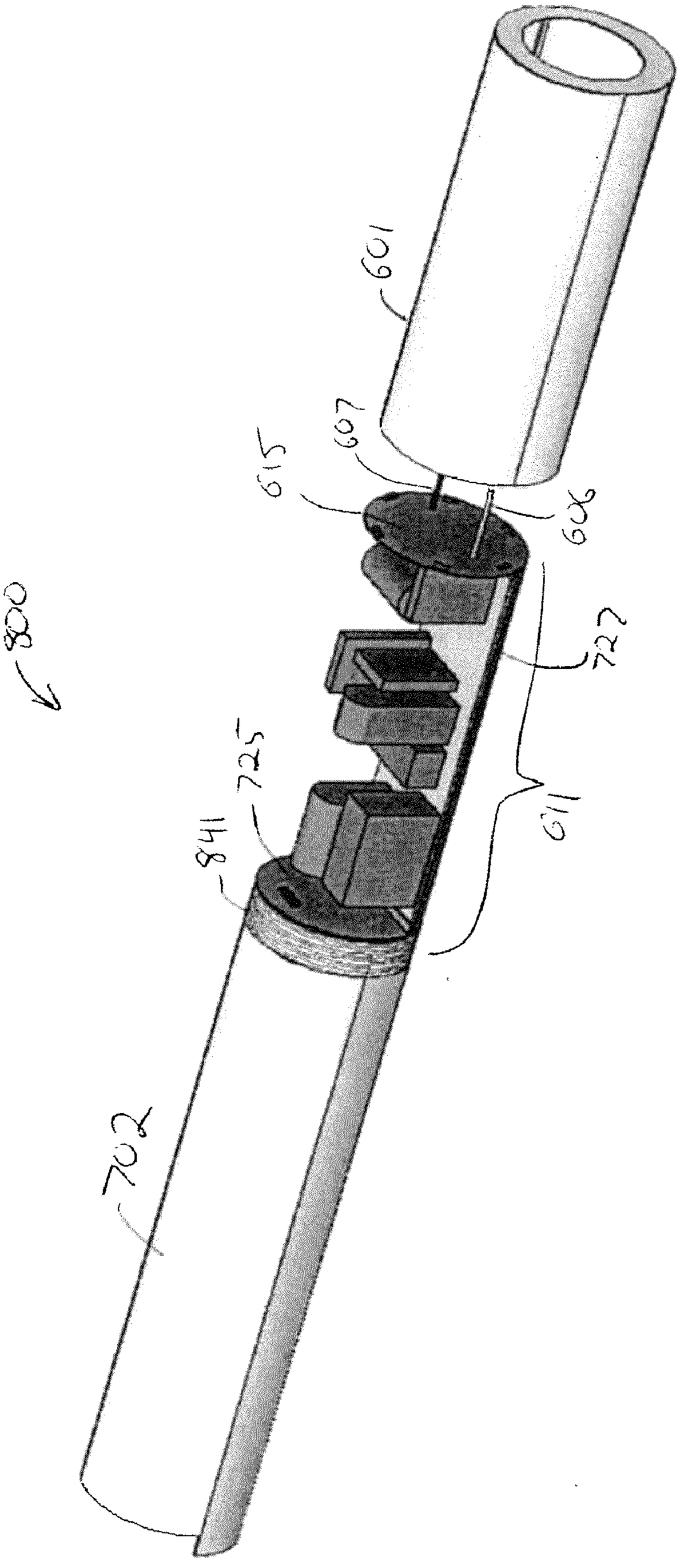


FIG. 7B

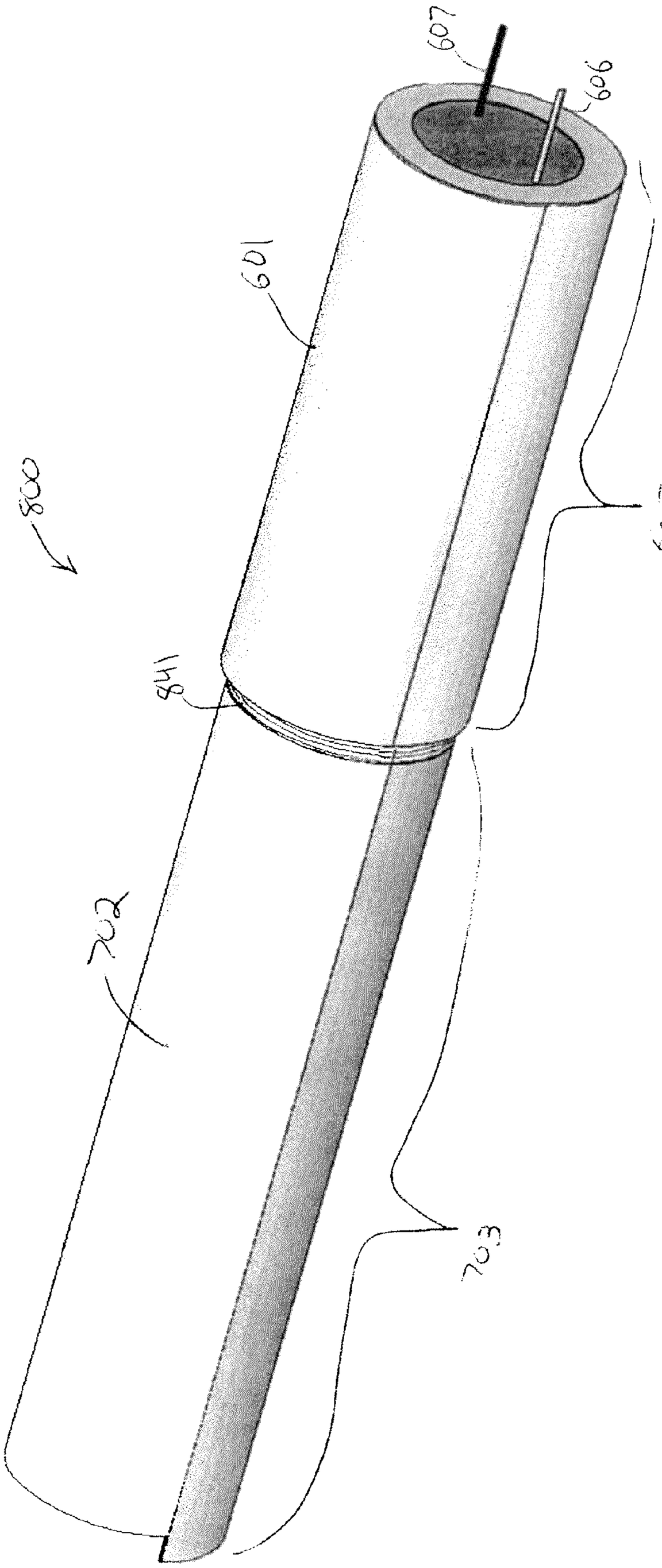


Fig. 9C

MODULAR LED LIGHTING SYSTEM

RELATED APPLICATIONS

This application is a continuation-in-part of and claims the benefit of U.S. patent application Ser. No. 12/621,351 filed on Nov. 18, 2009, the content of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

The present invention relates generally to lighting systems, and more particularly, some embodiments relate to modular lighting systems.

DESCRIPTION OF THE RELATED ART

Light emitting diodes (LEDs) represent an attractive option as a potential replacement technology for incandescent and fluorescent lighting systems. LED lighting systems are often more efficient and frequently have a much longer potential life span than the systems they are designed to replace. For example, a typical LED light tube for replacement of a fluorescent troffer style light bulb may have a rating of more than 50,000 hours.

Different components that make up an LED light system may have varying costs and lifespans. The these different components may all have varying lifespans. Accordingly, the lifespan of the light as a whole is generally limited to the first component to break. In some cases, the LEDs themselves might have a virtually unlimited lifespan when kept under proper temperatures. The LED driver or ballast may be a major contributing factor in lifespan. For example, the LED driver itself may have a limited lifespan, for example 20,000-50,000 hours. Furthermore, different components can effect the lifespans of other components through their interactions. For example, the LED driver may generate heat that reduces the lifespan of the LEDs. Accordingly, for LED systems having fixed components, the lifespan of such a system is no greater than 20,000-40,000 hours.

BRIEF SUMMARY OF EMBODIMENTS OF THE INVENTION

According to various embodiments of the invention, an LED lighting system is providing having a replaceable driver module. In some embodiments, the replaceable driver module comprises a component that is physically attachable to an LED illumination module, such that the attached components have a combined physical profile dimensioned for installation in a pre-existing light fixture. In further embodiments, the combined system's dimensions allow it to be installed in pre-existing fluorescent fixtures without requiring rewiring the fixtures. In some embodiments, the LED driver module may be configured to condition power received from a fluorescent light ballast to drive the LEDs such that a pre-existing fluorescent ballast does not need to be removed. In other embodiments, the LED driver may be configured to condition main power such that a pre-existing fluorescent ballast may be removed.

According to an embodiment of the invention, a modular lighting system comprises an illumination module comprising a first housing and a plurality of electrically coupled LEDs disposed within the within the first housing; a driver module comprising a second housing configured to physically couple and de-couple from the illumination module, and an LED driver disposed within the second housing and configured to provide an electrical current to drive the plurality of LEDs when the driver module is coupled to the illumination module.

According to a further embodiment of the invention, the illumination module and the driver module have form factors such the system is installable in a pre-existing troffer light fixture when the driver module is coupled to the illumination module.

Other features and aspects of the invention will become apparent from the following detailed description, taken in conjunction with the accompanying drawings, which illustrate, by way of example, the features in accordance with embodiments of the invention. The summary is not intended to limit the scope of the invention, which is defined solely by the claims attached hereto.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention, in accordance with one or more various embodiments, is described in detail with reference to the following figures. The drawings are provided for purposes of illustration only and merely depict typical or example embodiments of the invention. These drawings are provided to facilitate the reader's understanding of the invention and shall not be considered limiting of the breadth, scope, or applicability of the invention. It should be noted that for clarity and ease of illustration these drawings are not necessarily made to scale.

Some of the figures included herein illustrate various embodiments of the invention from different viewing angles. Although the accompanying descriptive text may refer to such views as "top," "bottom" or "side" views, such references are merely descriptive and do not imply or require that the invention be implemented or used in a particular spatial orientation unless explicitly stated otherwise.

FIG. **1** illustrates a side view and a perspective exploded view of an LED lighting system according to an embodiment of the invention.

FIG. **2** illustrates various side views of a driver module coupled to an illumination module according to an embodiment of the invention.

FIG. **3** illustrates side views and perspective views of a portion of an engaging module for a driver module according to an embodiment of the invention.

FIG. **4** illustrates a portion of an engaging module for an illumination module according to an embodiment of the invention.

FIG. **5** illustrates an alternative modular LED lighting system according to another embodiment of the invention.

FIG. **6** illustrates end and perspective views of an alternative driver module according to an embodiment of the invention.

FIG. **7** illustrates cross-sectional and perspective sectional views of an alternative illumination module according to an embodiment of the invention.

FIG. **8**A illustrates an exploded side view of a light tube assembly having a driver module coupled to an illumination module according to an embodiment of the invention.

FIG. **8**B illustrates a side sectional view of the light tube assembly of FIG. **8**A wherein the light tube and driver cradle are assembled.

FIG. **8**C illustrates a side sectional view of the fully assembled light tube assembly of FIG. **8**A.

FIG. **8**D illustrates a side sectional view of a portion of the light tube assembly of FIG. **8**A.

FIG. **9**A illustrates an exploded perspective view of the light tube assembly of FIGS. **8**A-**8**D having a driver module coupled to an illumination module according to an embodiment of the invention.

FIG. **9**B illustrates a perspective view of the light tube assembly of FIG. **9**A wherein the driver cradle is assembled.

FIG. **9**C illustrates a perspective view of the fully assembled light tube assembly of FIG. **9**A.

The figures are not intended to be exhaustive or to limit the invention to the precise form disclosed. It should be understood that the invention can be practiced with modification and alteration, and that the invention be limited only by the claims and the equivalents thereof.

DETAILED DESCRIPTION OF THE EMBODIMENTS OF THE INVENTION

The present invention is directed toward an LED lighting system having a replaceable, driver module. In some embodiments, the replaceable driver module comprises a component that is physically attachable to an LED illumination module, such that the attached components have a combined physical profile dimensioned for installation in a pre-existing light fixture. In further embodiments, the combined system's dimensions allow it to be installed in pre-existing fluorescent fixtures without requiring rewiring the fixtures. In some embodiments, the LED driver module may be configured to condition power received from a fluorescent light ballast to drive the LEDs such that a pre-existing fluorescent ballast does not need to be removed. In other embodiments, the LED driver may be configured to condition main power such that a pre-existing fluorescent ballast may be removed. In further embodiments, other components of the LED light system are also replaceable.

In various embodiments, the replaceability of the modules described herein allows the modules to be repaired or upgraded, thereby eliminating the need to replace the entire module for technological upgrades or system failures. For example, future LEDs may be produced that are more efficient or that have more desired light characteristics, such as a greater luminosity or more preferred color temperature. Accordingly, the some embodiments described herein, an illumination module may be replaced with such an upgraded LED technology with requiring entire system replacement.

The replaceable modules described herein also ease the reparability of the described systems. For example, the replaceability of a driver module, as described herein, allows failed driver modules to be repaired. In some such embodiments, the driver modules themselves have replaceable, upgradeable, or reparable modularity. For example, rather than a sealed driver module, a driver module may be open such that its components are accessible and replaceable or upgradeable. Furthermore, replacing or repairing components of the system in a modular fashion significantly reduces the carbon footprint of the system as a whole over systems requiring complete replacement when any component fails.

FIG. **1** illustrates a side view **100** and a perspective exploded view **110** of an LED lighting system according to an embodiment of the invention. The illustrated embodiment comprises a driver module **105** that is attachable to an LED illumination module **103**. The illustrated driver module **105** comprises a driver circuit **111** disposed within a driver housing **101**. A pair of electrical contacts **106** are further attached to the housing **101** and are electrically coupled to the driver circuit **111**. In various embodiments, driver circuit **111** may comprise any suitable electrical circuit configured to condition electricity for powering a plurality of LEDs **109**. For example, the driver circuit may comprise a conventional constant current source configured to convert electricity received via contacts **106** to have suitable characteristics for LED use.

The illustrated illumination module **103** comprises a housing **102** having a plurality of LEDs **109** disposed within. In this embodiment, the LEDs are configured to be powered by electricity received from the driver module **105** when the illumination module **103** is connected to the driver module **105**. In some embodiments, the LEDs may be coupled to a circuit board **108** in a conventional manner, and the circuit board **108** may be configured such that it is placed in electrical communication with pins **106** and LED driver circuit **111** when the driver module **105** is coupled to the illumination module **103**.

In some embodiments, coupling between the driver module **105** and the illumination module **103** may be mediated by a coupling module **107**. In the illustrated embodiment, coupling module **107** comprises a cap **107** that is configured to engage with the housing **102** of illumination module **103**. In some embodiments, cap **107** may be configured to be disengageable, for example to allow eventual replacement of the LED board **109**, thereby further increasing system usefulness. Cap **107** further comprises a receptacle that is configured to receive the housing **101** of the LED driver module **105** in a removable manner. In some embodiments, the removeablity of LED driver module **105** allows the driver module **105** to be replaced after the driver **111** has reached its end of life. Accordingly, the lifetime of the illustrated LED lighting system may be extended so that it is limited by the LED illumination module **103**'s lifetime duration rather than the driver **111**'s lifetime. Further, in the illustrated embodiment, the driver module **105** is physically displaced from the illumination module **103**. Accordingly, heat generated by the driver module **105** may dissipate during system operations without significantly impacting the heat conditions inside the illumination module **103**. In such embodiments, heat sinks within the illumination module **103** may be chosen according to the heat generation characteristics of the LEDs without regard to the heat generation characteristics of the LED driver circuit **111**. In typical embodiments, the LEDs themselves may generate significantly less heat than the driver circuit **111**. Accordingly, in these embodiments, a smaller and more cost-efficient heat sink may be employed within the illumination module **103** than would be required with an internally disposed driver circuit.

A second cap **113** may further be provided to engage with the housing **102** of illumination module **103**. In some embodiments, this cap **113** may be permanently joined with the housing **102** to provide a permanent electrical interface between pins **106** and the LED circuit **108**. In other embodiments, cap **113** may be configured to be removable, for example to environmentally seal the illumination module **103** when in place and to allow replacement of LED circuit **108** when removed.

As illustrated, when a driver module **105** is coupled to the illumination module **103**, the combined system has a dimensionality **104**. In the illustrated embodiment, the combined system has a tubular profile that is dimensioned for installation in a pre-existing fluorescent light troffer fixture. For example, the system may have a diameter and length allowing it to be installed in a "T" designation fluorescent fixture, such as a T5, T8, or T12 lamp fixture. In these embodiments, electrical contacts **106** may comprise pins configured to engage with a pre-existing troffer's double or single pin sockets, or "tombstones."

In further embodiments, other physical profiles may be employed such that the system may be installable in other

fixture types. For example, a standard LED fixture, a standard incandescent light fixture, or a circular fluorescent standard. In some environments, for example an environment employing troffer style fluorescent fixtures, the fixtures may be provided with existing ballast circuitry. For example, a tubular fluorescent light fixture may have a corresponding installed fluorescent light ballast in electrical contact with the fixture. Accordingly, in some embodiments, the driver circuit **111** may be pre configured to condition the type of power generated by the fluorescent light ballast into a suitable profile for powering the LED circuit **108**. In such an embodiment, an installer would not be required to rewire an existing fixture, and could simply install the embodiment as a replacement light tube. In other embodiments, the driver **111** could be configured to condition other power, such as main electricity, to power the LED circuit **108**. For example, such embodiments might be employed to replace pre-existing fluorescent fixtures as their fluorescent ballasts fail, or as a wholesale replacement of a fluorescent lighting system without requiring the physical remodeling that would be required to replace the fluorescent troffer systems. Further, direct conversion of main power may be more energy efficient than conversion of ballast power, so energy savings may be gained by electrically bypassing a pre-existing fluorescent ballast.

FIG. **2** illustrates various side views of a driver module coupled to an illumination module according to an embodiment of the invention. View **114** is a side view of a driver circuit **111** as it would appear with housing **101** removed. View **115** is a cutaway side view of an illumination system, and view **116** is a cutaway side view rotated 90° with respect to view **115**. In the illustrated embodiment, a coupling module **107** is fixedly connected to the illumination module **103**, and in some embodiments may comprise, a component of illumination module **103**. A corresponding coupling module **112** may be joined to the housing **101** of the driver module **105**. As illustrated, the first coupling module **107** may comprise a receptacle configured to receive the second coupling module **112** when the driver module is engaged with the illumination module. As further illustrated, this engagement allows the driver circuit **111** to electrically couple to the LED circuit **108**, and maintains this coupling during system operation. In various embodiments, this coupling may be obtained in various ways. For example, coupling module **112** may be configured to screw into coupling module **107** or vice versa; the coupling modules **112** and **107** may be configured to frictionally engage one another; or one coupling module may be engaged with the other through notches or other means of connection. Although illustrated as separate structures, in some embodiments, coupling modules **112** and **107** may be integrated into the structures of the driver module **105** or the illumination module **103**. For example, coupling module **112** part of a continuous structure formed by coupling module **112** and housing **101**. Similarly, coupling module **107** may form part of a continuous structure formed by coupling module **112** and housing **102**.

In further embodiments, various mechanisms may be deployed to indicate the status of various components of the systems described herein. For example, an LED **130** or an LED **131** may be coupled to the driver module or illumination module, respectively, to indicate the health of the driver module. Such an LED may be electrically coupled to the driver circuit **111**. In the case of an LED **130** coupled to the driver module **105**, the LED **130** may be disposed in the housing **101**, or a window may be disposed in housing **101**, and the LED **130** may be in permanent electrical connection to the driver circuit **111**. In the case of an LED **131** coupled to the illumination module **103**, the LED **131** may be configured to electrically couple to the driver circuit **111** when the driver module **105** is coupled to the illumination module **103**. In either case, the LED **130** or **131** may be configured to activate if a component in the driver circuit **111** is close to failure. Accordingly, a system user or maintainer can be alerted to an impending failure and replace the driver module **105** before the system is deactivated.

FIG. **3** illustrates side views and perspective views of a portion of an engaging module for a driver module according to an embodiment of the invention. In the illustrated embodiment, the engaging module comprises a cap **112** for a driver module that engages with a corresponding cap for an illumination module (illustrated in FIG. **4**). FIG. **3**A illustrates front perspective and back perspective views of a cap **112**, whereas FIG. **3**B illustrates a side view and a cutaway side view of cap **112**. With further reference to FIG. **2**, the illustrated cap **112** is configured to engage with the housing **101** of the driver module **105** to provide a means of releasable engaging with an illumination module **103**. In the illustrated embodiment, the cap **112** is connected to the driver housing **101** at a first side. For example, a plurality of tabs **119** may be disposed on the first side to engage with corresponding notches in the driver housing **101** such that the cap is fixed to the housing during normal operations. In some embodiments, this connection to the housing **101** may also be releasable. For example, the cap **112** may be configured to remain in place during normal systems operations, and during replacement of the driver module **105**. Furthermore, the cap **112** may be configured so that it is removable after the driver module **105** has been removed from the illumination module. For example, a defective or used driver module **105** may be repaired by removing the cap **112** and replacing the driver circuit disposed in the module.

In the illustrated embodiment, the cap **112** is configured to engage with a corresponding portion of the illumination module **103** to allow the driver module to be replaceable. Here, the means of engagement comprises a groove **117** that is disposed on the connecting side. This groove engages with a corresponding tab on the illumination module, as described below, to provide a means of engagement whereby the driver module can be connected to the illumination module by threading the groove **117** with the tab by displacing the driver module parallel to the axis of the tube and then by rotating the driver module about the axis, such that the illumination module and driver module releasable lock together. The illustrated embodiment further comprises a portal **118** configured to allow electrical coupling between the driver circuit **111** and the LED circuit **108**.

FIG. **4** illustrates a portion of an engaging module for an illumination module according to an embodiment of the invention. In the illustrated embodiment, the engaging module comprises a cap **107** for the illumination module **103** that engages with a corresponding cap for the driver module (as illustrated in FIG. **3**). FIG. **4** comprises a cutaway side view, a front perspective view, and a rear perspective view of cap **107**. The illustrated embodiment comprises a portion **119** configured to engage with the housing **102** of the illumination module **103**. For example, the housing **102** may be inserted into the portion **119** and kept in place through tabs or through compressive force provided by a plurality of ridges **120**. In some embodiments, the portion **119** may be configured to maintain the connection to the housing **102** during normal system operations but may be removable after the system has been disassembled. For example, the cap **107** may be removable from the illumination module **103** to allow the illumination circuit **108**, or other components such as heat sinks, to be removed or replaced as needed.

The illustrated embodiment further comprises a portion **122** configured to engage with the cap **112** of the driver module **105**. As illustrated, and as described above, the portion **122** further comprises a tab **123** that engages with a groove **117** disposed on cap **112**. Accordingly, the driver module may be coupled to the illumination module by inserting the cap **112** portion of the driver module into portion **122** such that the groove **117** engages with the tab **123** to releasable lock the driver module into place. Similar to cap **112**, the illustrated cap **107** further comprises a portal **121** configured to allow electrical flow between the driver circuit **111** and the LED circuit **108**.

FIG. **5** illustrates an alternative modular LED lighting system according to another embodiment of the invention. In this embodiment, a replaceable driver module **151** comprises an internally replaceable driver module **151** that is configured to engage with an LED circuit comprising a plurality of LEDs on a circuit board electrically coupled to the driver **151**. In this embodiment, the internal driver module **151** is maintained within the tube **150** through a cap **158** that engages with tube **150** in a releasable manner, for example through a similar tab and groove system as described with respect to FIGS. **4** and **5**. Accordingly, in this embodiment, the driver module **151** is replaceable by removing the cap **158** to allow access to the driver module **151**. In some embodiments, a second driver module **153** may be provided, for example as a backup to the first driver module **151**. In some of these embodiments, the tube **150** may comprise a storage for the second driver module **153**, such that driver module **153** may be used to replace driver module **151** when it ceases functioning. In further embodiments, the driver module **153** may be equipped with its own electrical connection to LED circuit **152** such that driver module **153** may be used to power the LED circuit **152** when the first driver module **151** fails without moving the second driver module **153**.

The illustrated embodiment further comprises a variety of additional components that may be employed in some embodiments alone or in combination. For example, an internal heat sink **154** may be disposed within the tube **150**. In some embodiments, this heat sink may be permanently joined with the tube **150**, for example, if the tube **150** was made of a heat conducting material, and a portion of the tube were configured to extend to engage or contact the driver circuit **152**. In other embodiments, the heat sink **154** may be removable and replaceable, for example through the same means **158** used for replacing the driver module **151**.

An internal diffuser or lens **155** may further be provided to cause the lighting system to provide a more diffuse or distributed light, or to focus or direct the light produced during systems operation to a particular location. In some embodiments, this internal diffuser or lens **155** may also comprise a material component of the tube **150**, or the diffuser or lens **155** may be removable or replaceable. In further embodiments, external diffusers or lenses **156** or external heat sinks **157**, or a combination of any of these components, may be employed. Accordingly, various system configurations may be formed by choosing various combinations of such components. Furthermore, although discussed with respect to the embodiment of FIG. **5**, these components **154**, **155**, **156**, and **157** may be employed and implemented in embodiments described with respect the other Figures and accompanying descriptive material.

FIG. **6** illustrates end and perspective views **602**, **603**, respectively, of an alternative driver module **605** according to an embodiment of the invention. Similar to previous driver module embodiments, the driver module **605** is attachable to an LED illumination module (e.g., LED illumination module **103** of FIG. **2**). The driver module **605** comprises a driver circuit disposed within driver housing **601**. This embodiment features an alternative pin arrangement, wherein metallic pin **606** comprises an electrical contact **606** providing an AC electrical connection, and non-metallic pin **607** provides a fixture specific non-electrical connection. Electrical contact **606** is electrically coupled to the driver circuit within driver housing **601**. The driver circuit may comprise any suitable electrical circuit configured to condition electricity for powering a plurality of LEDs. For example, the driver circuit may comprise a conventional constant current source configured to convert electricity received via contact **606** to have suitable characteristics for LED use.

FIG. **7** illustrates cross-sectional and perspective sectional views **701**, **704**, respectively, of an alternative illumination module **703** according to an embodiment of the invention. The illustrated illumination module **703** comprises a housing **702** having a circuit board **708** with a plurality of LEDs **709** disposed therein. In this embodiment, the housing **702** comprises a dual lens tube **702** having a first section **712** and a second section **713** comprising tube halves separated by a plane defined by circuit board **708**. These tube sections **712**, **713** may comprise various combinations of lenses including, but not limited to, clear, frosted, colored, warm white and cool white lenses. By way of example, section **712** may comprise a clear lens, while section **713** may comprise a frosted lens. In another example, section **712** may again comprise a clear lens, whereas section **714** may comprise a colored lens. Any combination of lenses may be employed to create a dual lens tube **702**. To change the quality of light emitted by illumination module **703**, a user removes the circuit board **708** from the dual lens tube **702** by sliding it out of the tube through guides **715**, rotates its orientation such that the LEDs **709** face the opposite tube section **712**, and slides the circuit board **708** back into the dual lens tube **702** through guides **715**.

Similar to previous embodiments, the LEDs **709** are configured to be powered by electricity received from the driver module (such a driver module **105** or driver module **605**) when the illumination module **703** is connected to the driver module. In some embodiments, the LEDs **709** may be coupled to a circuit board **108** in a conventional manner, and the circuit board **708** may be configured such that it is placed in electrical communication with pin(s) (e.g., pins **106** or pin **606**) and the LED driver circuit when the driver module is coupled to the illumination module **703**.

FIG. **8**A illustrates an exploded side view of the light tube assembly **800** having a driver module **605** coupled to an illumination module **703** according to an embodiment of the invention. Similar to previous embodiments, the driver module **605** comprises a driver circuit **611** disposed within a driver housing **601**. FIG. **8**B illustrates a side sectional view of the light tube assembly **800** of FIG. **8**A wherein the light tube and driver cradle are assembled, FIG. **8**C illustrates a side sectional view of the fully assembled light tube assembly **800**, and FIG. **8**D illustrates a side sectional view of a portion of the light tube assembly **800**.

Referring to FIGS. **8**A-**8**D, the illumination module **703** comprises a dual lens tube **702** having first and second section tube sections **712**, **713** that may comprise various combinations of lenses including, but not limited to, clear, frosted, colored, warm white and cool white. The driver end **717** of the dual lens tube **702** may be attached to the driver housing **601** by any number of means. By way of example, the tube **702** and driver housing **601** may be screwed together, attached via snap fit or twist pressure, attached via slots, or glued together. In some embodiments, this connection may feature an additional tension ring. The other end **719** of the tube **702** may

include a single metallic pin **706** comprising an electrical contact **706** providing an AC electrical connection to the driver circuit **611**. Some embodiments may feature a second pin comprising a non-metallic pin providing a fixture specific non-electrical connection.

The illumination module **703** further comprises a circuit board **708** having a plurality of LEDs **709** disposed within. The circuit board **708** features a DC electrical connector **721** that may be disconnected from DC wires **722** to allow light element upgrade, replacement, or rotating to allow a different light quality, such as described with respect to FIG. **7**. In addition, the circuit board includes an AC connection **723** at the isolator section **725** of the driver cradle **727**. An alignment slot **729** is provided within the driver cradle **727** to provide a guide for the circuit board **708** such that the circuit board **708** may slide into the slot **729** to provide the AC connection. The isolator **725** comprises a wall that insulates the driver module **605** from the illumination module **703**. The driver module **605** is detached from the illumination module **703** to allow for replacement or repair of the driver. A single metallic pin **606** comprising an electrical contact **606** is provided at the end **615** of the driver to provide AC power. In the illustrated embodiment, an AC connection is provide from both ends of the light tube assembly (i.e., pins **606**, **706**) via a wire or wires that extend through the light tube assembly **800** from pins **606**, **706** to the driver circuit **611**.

Referring to FIG. **8**D, the driver module **605** of the light tube assembly **800** is depicted in cross-section and the cross flow ventilation of the driver module **605** is illustrated. Specifically, the airflow within the driver module **605** is depicted by arrows **830**. The airflow is subject to the physics of the air, which causes the air to flow from hotter to cooler locations. Slots **833** in the driver housing **601** at the junction of the illumination module **703** and the driver module **605** are formed to allow air to flow into the driver module **605**. Additional slots **835** are provided at the other end **615** of the driver housing **601** to allow the heated air to flow out of the driver module **605**.

FIG. **9**A illustrates an exploded perspective view of the light tube assembly **800** of FIGS. **8**A-**8**D having a driver module **605** coupled to an illumination module **703** according to an embodiment of the invention. Similar to previous embodiments, the driver module **605** comprises a driver circuit **611** disposed within a driver housing **601**. FIG. **9**B illustrates a perspective view of the light tube assembly **800** of FIG. **9**A wherein the driver cradle is assembled, while FIG. **9**C illustrates a perspective view of the fully assembled light tube assembly **800**.

Referring to FIGS. **9**A-**9**C, in the illustrated embodiment the tube **702** and driver housing **601** are screwed together via threads **841** on tube **702** and corresponding threads (not shown) within driver housing **601**. In some embodiments, this connection may feature an additional tension ring. The driver housing **601** is detached from the tube **702** to allow for replacement or repair of the driver. This embodiment features an alternative pin arrangement, wherein metallic pin **606** comprises an electrical contact **606** providing an AC electrical connection, and non-metallic pin **607** provides a fixture specific non-electrical connection. Electrical contact **606** is electrically coupled to the driver circuit within driver housing **601**.

While various embodiments of the present invention have been described above, it should be understood that they have been presented by way of example only, and not of limitation. Likewise, the various diagrams may depict an example architectural or other configuration for the invention, which is done to aid in understanding the features and functionality that can be included in the invention. The invention is not restricted to the illustrated example architectures or configurations, but the desired features can be implemented using a variety of alternative architectures and configurations. Indeed, it will be apparent to one of skill in the art how alternative functional, logical or physical partitioning and configurations can be implemented to implement the desired features of the present invention. Also, a multitude of different constituent module names other than those depicted herein can be applied to the various partitions. Additionally, with regard to flow diagrams, operational descriptions and method claims, the order in which the steps are presented herein shall not mandate that various embodiments be implemented to perform the recited functionality in the same order unless the context dictates otherwise.

Although the invention is described above in terms of various exemplary embodiments and implementations, it should be understood that the various features, aspects and functionality described in one or more of the individual embodiments are not limited in their applicability to the particular embodiment with which they are described, but instead can be applied, alone or in various combinations, to one or more of the other embodiments of the invention, whether or not such embodiments are described and whether or not such features are presented as being a part of a described embodiment. Thus, the breadth and scope of the present invention should not be limited by any of the above-described exemplary embodiments.

Terms and phrases used in this document, and variations thereof, unless otherwise expressly stated, should be construed as open ended as opposed to limiting. As examples of the foregoing: the term "including" should be read as meaning "including, without limitation" or the like; the term "example" is used to provide exemplary instances of the item in discussion, not an exhaustive or limiting list thereof; the terms "a" or "an" should be read as meaning "at least one," "one or more" or the like; and adjectives such as "conventional," "traditional," "normal," "standard," "known" and terms of similar meaning should not be construed as limiting the item described to a given time period or to an item available as of a given time, but instead should be read to encompass conventional, traditional, normal, or standard technologies that may be available or known now or at any time in the future. Likewise, where this document refers to technologies that would be apparent or known to one of ordinary skill in the art, such technologies encompass those apparent or known to the skilled artisan now or at any time in the future.

The presence of broadening words and phrases such as "one or more," "at least," "but not limited to" or other like phrases in some instances shall not be read to mean that the narrower case is intended or required in instances where such broadening phrases may be absent. The use of the term "module" does not imply that the components or functionality described or claimed as part of the module are all configured in a common package. Indeed, any or all of the various components of a module, whether control logic or other components, can be combined in a single package or separately maintained and can further be distributed in multiple groupings or packages or across multiple locations.

Additionally, the various embodiments set forth herein are described in terms of exemplary block diagrams, flow charts and other illustrations. As will become apparent to one of ordinary skill in the art after reading this document, the illustrated embodiments and their various alternatives can be implemented without confinement to the illustrated examples. For example, block diagrams and their accompa-

nying description should not be construed as mandating a particular architecture or configuration.

The invention claimed is:

1. A modular lighting system, comprising:

an illumination module comprising a first housing and a plurality of electrically coupled LEDs disposed within the within the first housing; and

a driver module comprising a second housing configured to physically couple and de-couple from the illumination module, and an LED driver disposed within the second housing and configured to provide an electrical current to drive the plurality of LEDs when the driver module is coupled to the illumination module;

wherein the illumination module and the driver module each include a single metallic pin comprising an electrical contact for providing an AC electrical connection to the LED driver.

2. The system of claim **1**, wherein the illumination module and the driver module each include a second pin comprising a non-metallic pin for providing a fixture specific non-electrical connection.

3. The system of claim **1**, wherein the driver module further comprises a cap coupled to the second housing and configured to interface with the illumination module to couple the driver module to the illumination module.

4. The system of claim **3**, wherein the cap is removable from the second housing and the LED driver is removable from the second housing when the cap is removed.

5. The system of claim **3**, wherein the illumination module further comprises a sealing element coupled to the first housing and configured to engage with the cap of the driver module when the driver module is coupled to the illumination module.

6. The system of claim **5**, wherein the sealing element is manually removable to allow replacement of at least one of the LEDs.

7. The system of claim **1**, wherein the LEDs are electrically coupled to a printed circuit board disposed within the housing, and wherein the illumination module further comprise a heat sink disposed within the first housing.

8. The system of claim **1**, wherein the illumination module and the driver module have form factors such the system is installable in a pre-existing troffer light fixture when the driver module is coupled to the illumination module.

9. The system of claim **1**, wherein the first housing comprises a dual lens tube having a first section and a second section comprising tube halves separated by a plane defined by an LED circuit board.

10. The system of claim **9**, wherein the tube halves comprise a combination of lenses selected from the group consisting of clear lenses, frosted lenses, colored lenses, warm white lenses and cool white lenses.

11. A driver module for an LED illumination system, comprising:

a first housing configured to physically couple and de-couple from an illumination module; and

an LED driver disposed within the first housing and configured to provide an electrical current to drive the plurality of LEDs when the driver module is coupled to the illumination module;

wherein the illumination module comprises a second housing and a plurality of electrically coupled LEDs disposed within the within the second housing;

wherein the first housing comprises a dual lens tube having a first section and a second section comprising tube halves separated by a plane defined by an LED circuit board.

12. The driver module of claim **11**, wherein the tube halves comprise a combination of lenses selected from the group consisting of clear lenses, frosted lenses, colored lenses, warm white lenses and cool white lenses.

13. The driver module of claim **11**, wherein the driver module further comprises a cap coupled to the first housing and configured to interface with the illumination module to couple the driver module to the illumination module.

14. The driver module of claim **13**, wherein the cap is removable from the first housing and the LED driver is removable from the first housing when the cap is removed.

15. The driver module of claim **13**, wherein the illumination module further comprises a sealing element coupled to the second housing and configured to engage with the cap of the driver module when the driver module is coupled to the illumination module.

16. The driver module of claim **15**, wherein the sealing element is manually removable to allow replacement of at least one of the plurality of the LEDs.

17. The driver module of claim **11**, wherein the LEDs are electrically coupled to the LED circuit board disposed within the housing, and wherein the illumination module further comprises a heat sink disposed within the first housing.

18. The driver module of claim **11**, wherein the illumination module and the driver module have form factors such the system is installable in a pre-existing troffer light fixture when the driver module is coupled to the illumination module.

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